Risk Evaluation Of Pipeline Network: Method, Computer Tools

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Evaluation of technological and ecological risks has been recently widely used for hazardous industries assessment. Standards that regulate industrial safety vary considerably from country to country, including differences in technological risk factors and procedures used to calculate those.

Specificity of assessment procedures depends upon a range of factors, including the nature of business (for pipeline systems, in particular, - the products transported), legislative and regulation bases, completeness of pipeline system data, assessment procedure targeted aims (designing, operation, reconstruction).

In Japan, in European and North-American countries specialized computer systems have been designed for risk factors evaluation. However, these systems cannot be applied in Russia. Required are the methods which account for the object technological specificity, for design and operation conditions data support. Specific computer technologies should be tailored to the method established.

Computer software designed by the authors is based upon risk factors evaluation, as including ecological and technogenic influences, network structure and network elements technical features. The pipeline risk factor is determined as average specific damage (per one kilometer of the route per year).

Factors as characterize technological risk were determined by means of expert poll. Different factors probability estimates are based upon expert verdicts and statistic data processing results.

The developed programme variant is intended to evaluate risk of the natural gas distribution system being designed and accounts for the following group of factors:

- Pipes mix (material, wall diameter and thickness, accepted operation pressure);
- Corrosivity determinants (inner covering, insulation covering, soils corrosivity, electrolytic protection, atmospheric conditions, etc.);
- Factors determining failures due to mistakes by operating organizations (gas distributors) and to stop valves breaking;
- Determinants of anthropogenic and environmental sensitivity of the element (pipeline depth, intersections with railroads, highways, power lines, water lines);
- Breakdowns and incidents aftereffects severity determinants (gas flow, quantity and importance of consumers, affected by the given element failure, area technogenic satiation, population density).

System potential failures are group-classified depending on the driving forces. There are four such groups introduced.

1 – internal and external corrosion,
2 – pipe faults, quality of construction and installation,
3 – operation personnel mistakes,
4 – anthropogenic and environmental impact.

The system is divided into elements. A pipeline section usually serves an element unit. Total risk for element i is calculated from the formula

$$R_i = W_1 R_{i1} + W_2 R_{i2} + W_3 R_{i3} + W_4 R_{i4}, \qquad (1)$$

where $i = 1,\ldots, I$ – total number of elements, W_1, W_2, W_3, W_4 – weights of enumerated factors. The weights are determined by means of expert analysis with the help of specially designed procedure. Values W_i are limited by the following condition

$$W_1 + W_2 + W_3 + W_4 = 1. \quad (2)$$

Each of the constituents R_{ij} $(j = 1,...,4)$ is calculated from the formula

$$R_{\bullet j} = P_{\bullet j} \times S_{\bullet j}, \quad (3)$$

where facient $P_{\bullet j}$ characterizes breakdowns and incidents potential rate (probability) for a pipeline section as caused by factors group *j*, $S_{\bullet j}$ characterizes aftereffects (losses, damage) severity. The point substitutes *i* –index, which stands for an element system number.

Complete system total risk is evaluated as based on the premises that each section weight (share) is proportional to the same section length and according to the following formula

$$R = \sum_{i=1}^{I} \frac{l_i}{L} R_i \quad L = \sum_{i=1}^{I} l_i, \quad (4)$$

where *L* is the system total length.

The system is designed for gas distribution networks risk evaluation. The programme works in interpretative mode in MS Windows (version 95 and higher) environment and is operated by geo-information system MapInfo.

The programme functional features:

- Generation of tables of initial data for calculation of gas distribution networks risk factors (Figure 1),
- System elements risk values calculation as based upon the generated tables and above described methodology,
- Visualization of risks distributed across the system elements (Figure 2),
- Visualization of risks area distribution (Figure 3).

The programme is usually applied to a gas distribution net designed for a settlement, gas transmission system of an administrative district or a constituent entity of the Federation. The software system includes several modules which are functionally divided into:

- Module for initial data collection,
- Module for technological risk values evaluation,
- Module for results visualization.

The first module (initial data collection) is designed to generate 5 tables and namely: gas pipelines table, gas consumers table, gas distribution stations table, administrative districts table and total data for all the districts table (total pipelines length, rural and urban gas consumption for existing sections of the network and those under design).

Initial data as required for risk values evaluation are essentially generated in the gas network sections table and in the total data for all the districts table. Initial data for grouping of the above-enumerated factors is put together in the former table. The bulk of these data is retrieved from the gas network sections table (section length, pipe diameter, material, etc.) to be structured with application of geographical queries in MapInfo (intersection with artificial and natural obstacles, local population density, etc.). Additional data non-anchorable in MapInfo to any gas distribution network object can be entered in the table generated by the user. The other tables are fields of numerical values of aggregated indices of technological risk for gas consumers, gas distribution stations and whole administrative districts. Using these tables the designer can assess impact by this or that element on the aggregated risk indices.

The second module allow to fill relevant fields of generated tables (Figure 1). For the sake of illustrate the resultant data are displayed on the thematic map (Figure 2) of gas distribution system objects. Colour-coding of these objects depend on the technological risk values.

The third module is designed to generate thematic map (Figure 3) of the district, a group of districts and whole constituent entity of the Russian Federation. The thematic map is plotted from evaluated technological risk aggregated indices. Colour scheme is determined according to specific

risk index of each district. Designed and existing gas pipelines technical risk chart is plotted for each district.

The designed system was applied to evaluate technical risk for administrative units of the Krasnodar Territory. Evaluation results proved practical acceptability of the designed system.

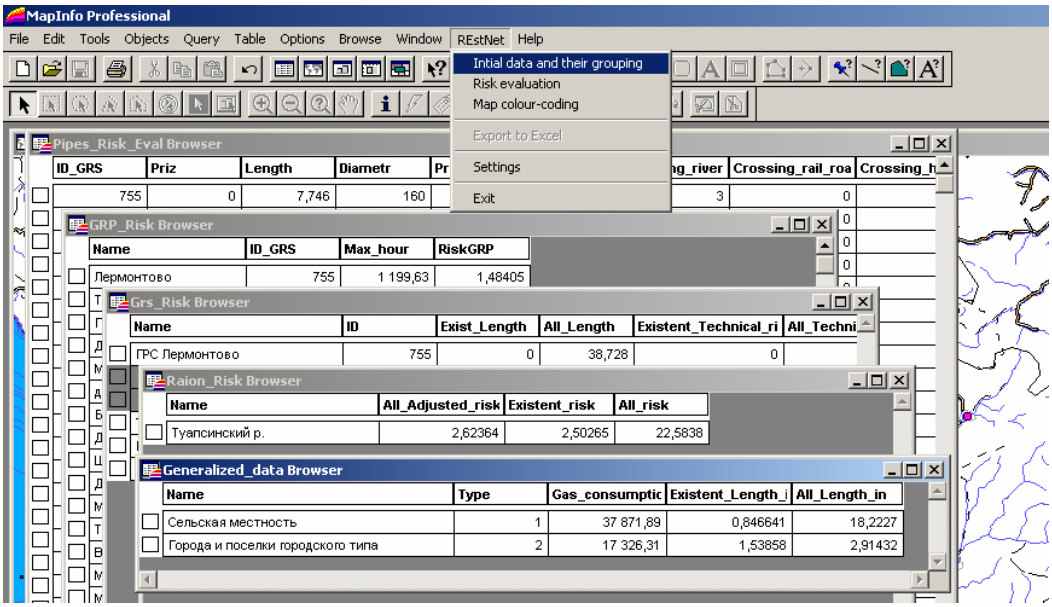

Figure 1. MapInfo table with initial data for technological risk indices evaluation.

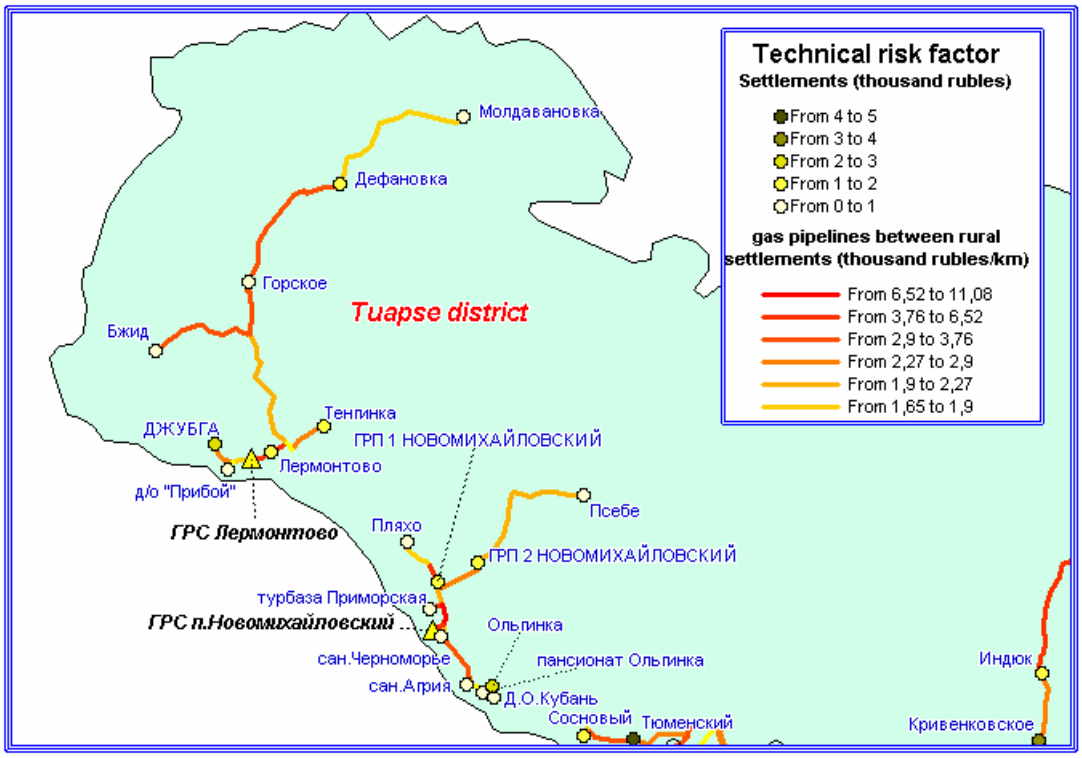

Figure 2. Thematic map sample (presented are gas pipeline specific risks and consumer technological risk indices)

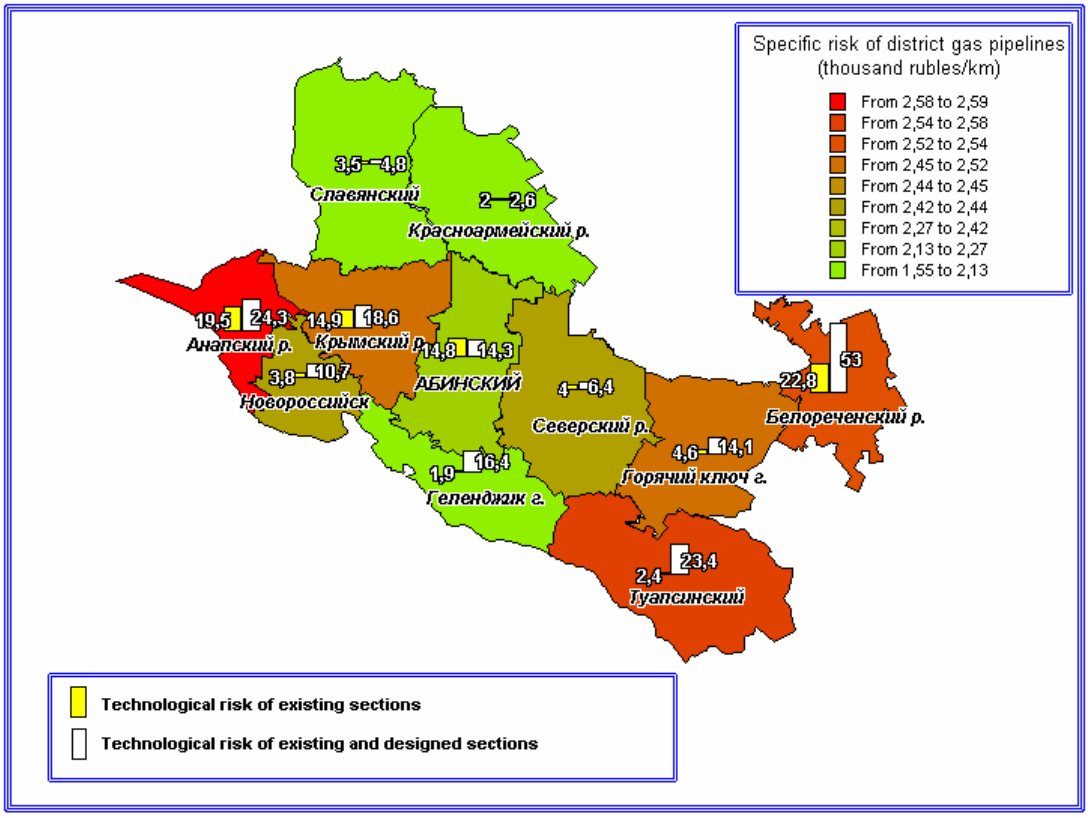

Figure 3. Total technological risks of gas distribution networks in several districts of the Krasnodar Territory